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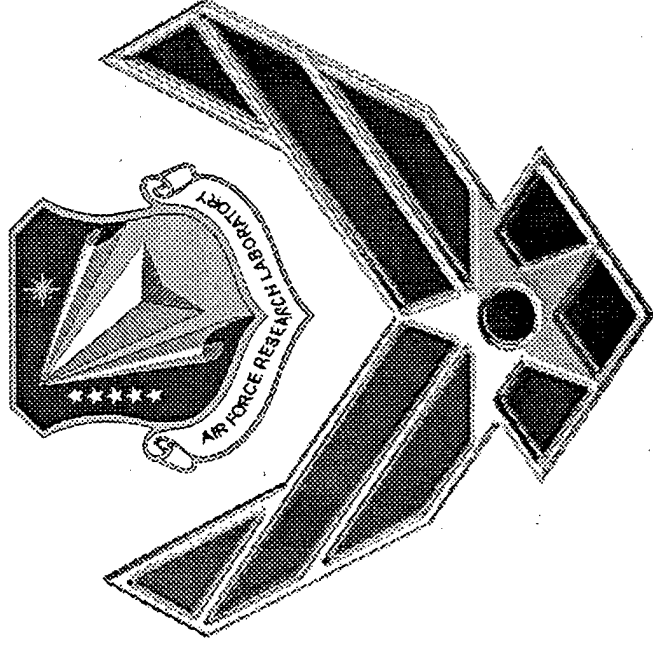
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SEM Annual Conf. on Experimental Mechanics
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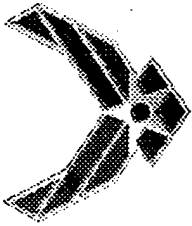
PRESSURE EFFECTS AND SURFACE CRACKS IN A RUBBERY PARTICULATE COMPOSITE

04 Jun 01



T. C. Miller
Engineer

Propulsion Directorate
Air force research laboratory



Introduction

Introduction

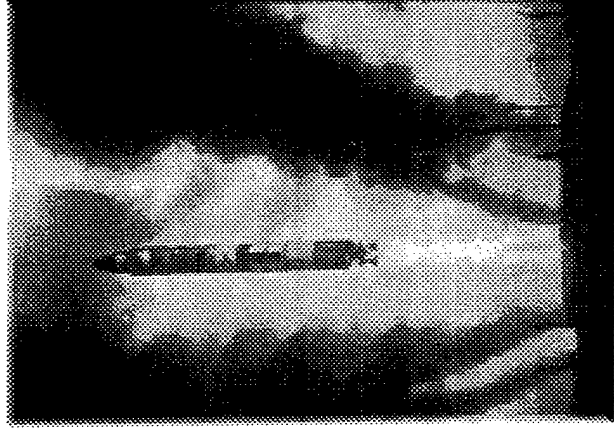
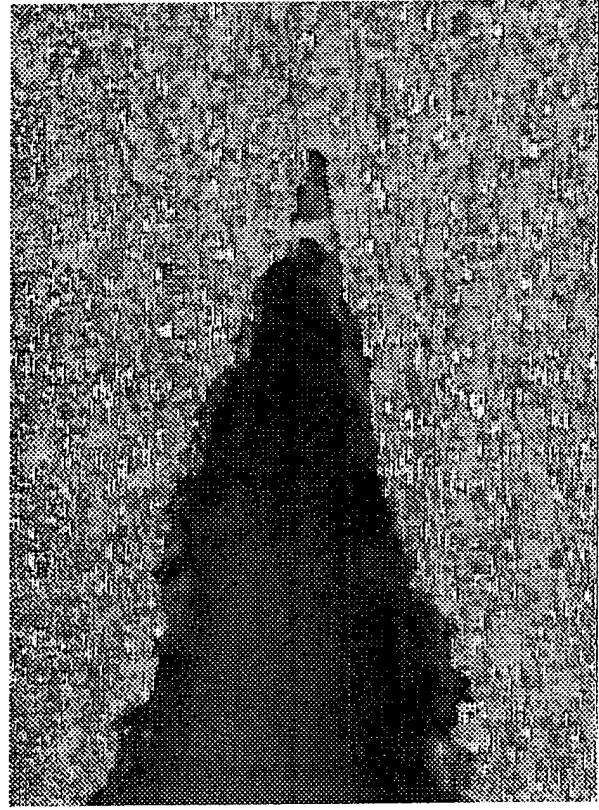
Experimental
Procedure

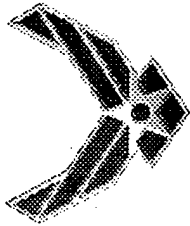
Analysis of
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Results and
Discussion

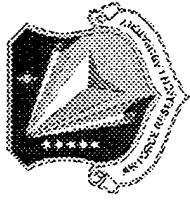
Summary and
Conclusions

- Cracks develop during manufacturing, handling, and storage of rubbery particulate composites
- Previous tests used single edge notched tension (SENT) specimens. In this work, surface cracked specimens are compared with the previous results
- Results for ambient and pressurized test conditions are also compared





Rubbery Particulate Composite Experiences Pressurization During Service Life



Introduction

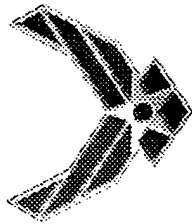
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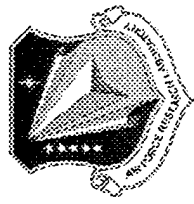
Results and
Discussion

Summary and
Conclusions

- Pressure affects fracture behavior by suppressing void nucleation, growth, and coalescence
- Both initiation of growth and subsequent growth rates are affected
- Applying ambient test data can result in overly conservative predictions



Experimental Procedure



Introduction

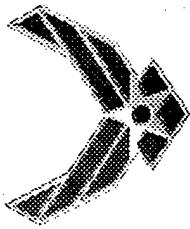
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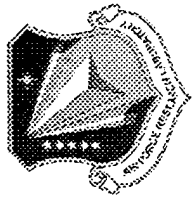
Results and
Discussion

Summary and
Conclusions

- Specimen geometries and test matrix
- Test conditions
- Equipment



Specimen Geometries and Test Matrix



Introduction

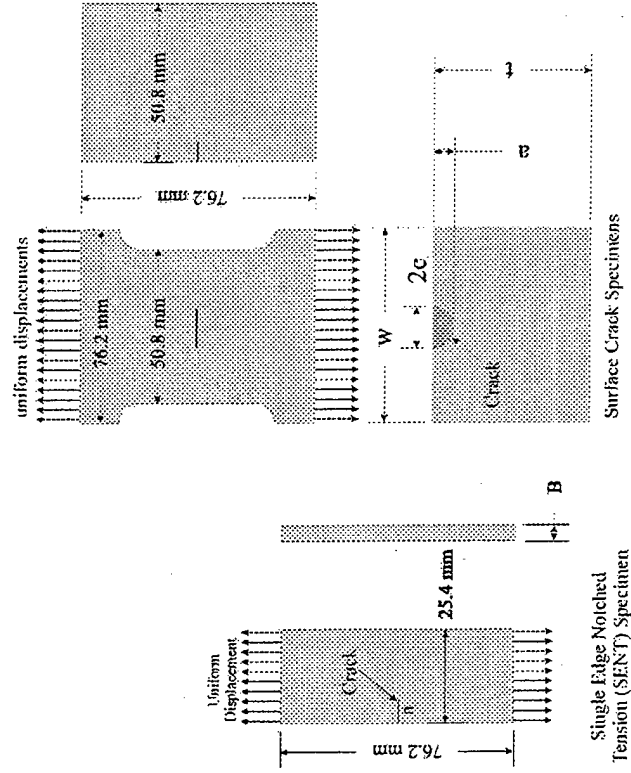
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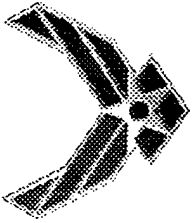
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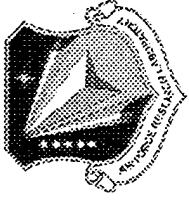
- Razor blade cutting devices used to form initial cracks
- Side cutouts needed for surface cracked specimens
- For SENT specimens, thickness and initial crack size were varied



| | | | | a_0 [mm] | |
|--|--------|------|------|------------|---|
| Number of SENT specimens tested | B [mm] | 2.54 | 7.62 | 12.70 | |
| | | | | | |
| | | | | | |
| | 5.08 | 3 | 3 | 3 | 3 |
| | 12.70 | 3 | 3 | 3 | 3 |
| | 38.10 | 3 | 3 | 3 | 3 |
| Number of surface cracked specimens tested | | | | 6 | |



Test Conditions



Introduction

Experimental
Procedure

Analysis of
Data

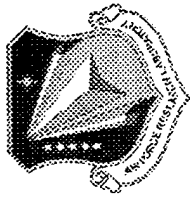
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Summary and
Conclusions

- Ambient temperature
- Ambient pressure and 6895 kpa pressure (nitrogen gas)
- Constant strain rate tests (0.067 mm/mm/min)



Equipment



Introduction

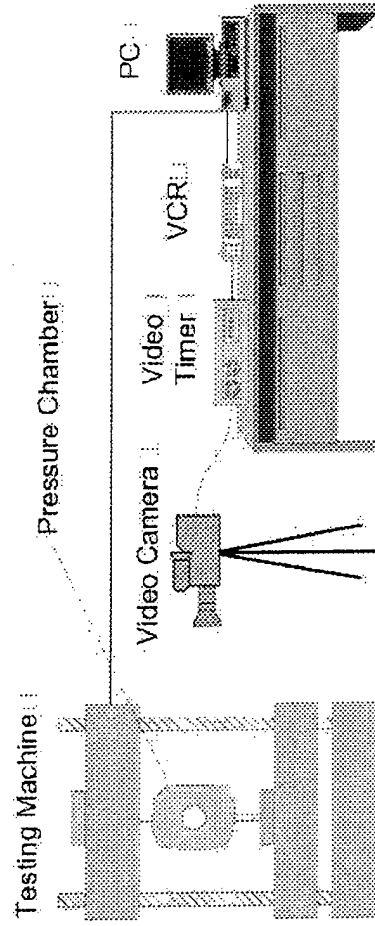
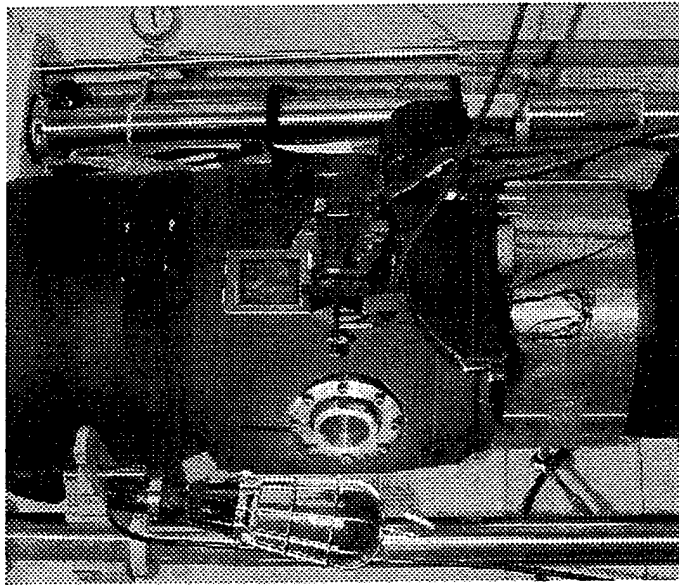
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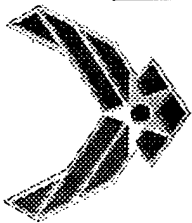
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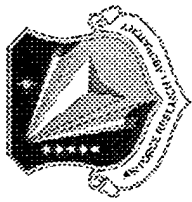
Summary and
Conclusions

- Testing machine
- Pressure test chamber
- Videotape equipment





Fixture Is Used to Apply Uniform Displacement Boundary Conditions



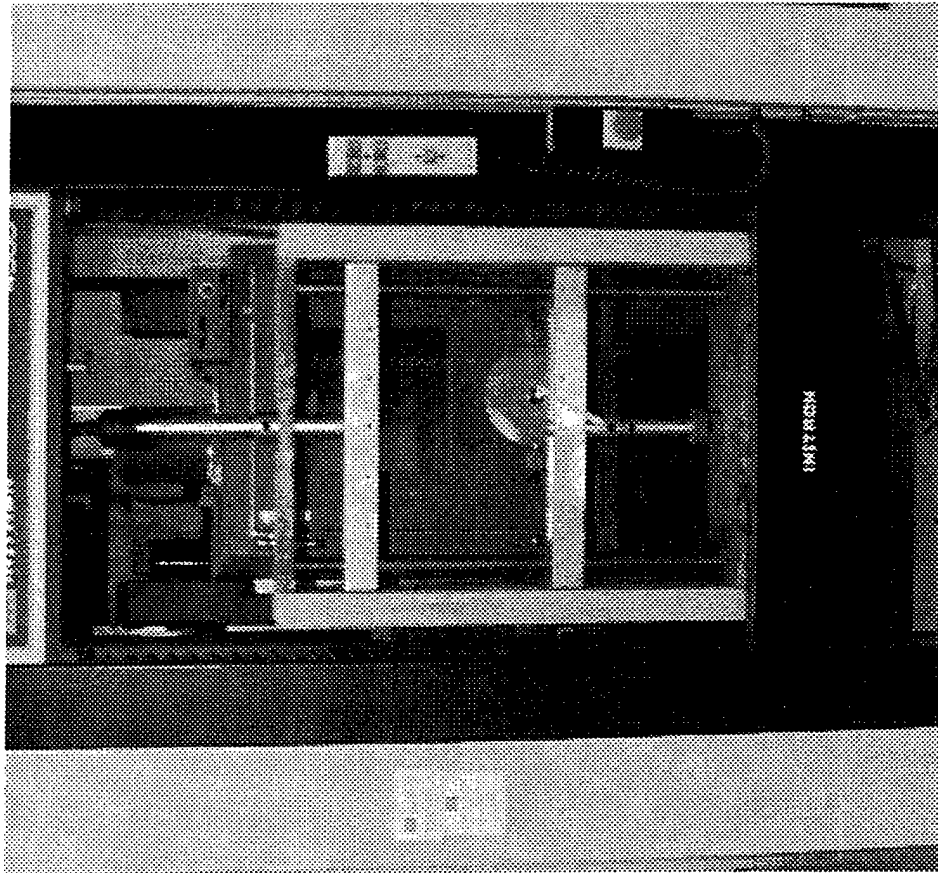
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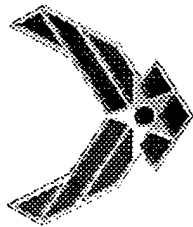
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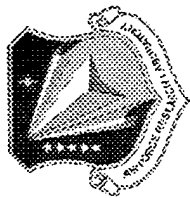
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Analysis of Data



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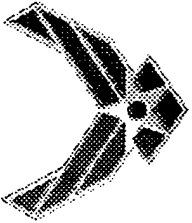
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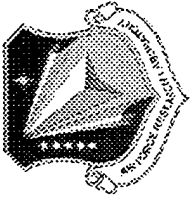
Summary and
Conclusions

- Step 1: data acquisition
- Step 2: determining da/dt and K_1
- Step 3: relating da/dt and K_1



Analysis of Data

Step 1: Data Acquisition



Introduction

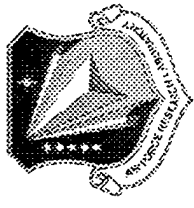
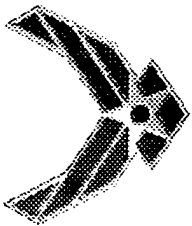
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Summary and
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- Use videotape to determine initiation of growth
- Use videotape to measure crack size vs. Time from initiation until maximum load
 - For surface cracks, depth could not be directly measured
- Use test machine data to determine loads at these same times



Analysis of Data

Step 2: Determining Da/dt and K_I

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Summary and
Conclusions

- Use load and geometric correction factors to determine K_I at these same times
 - Geometric correction factors come from finite element analyses
 - For surface cracks, semicircular crack front is assumed throughout growth
- Use crack size vs. Time data to determine da/dt at these same times
 - nonuniform* *I have a problem with "nonsmooth". Would something like "irregular" or "irregular" be better?*
– Crack speed is nonuniform due to microstructural phenomena
 - Polynomial curve fits of a vs. T are used; derivatives give growth rate



Nonuniform Crack Growth

Nonuniform irregular !!!



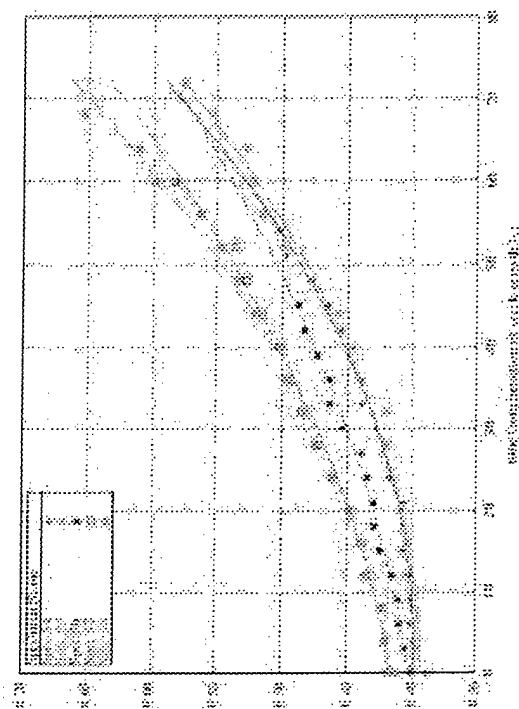
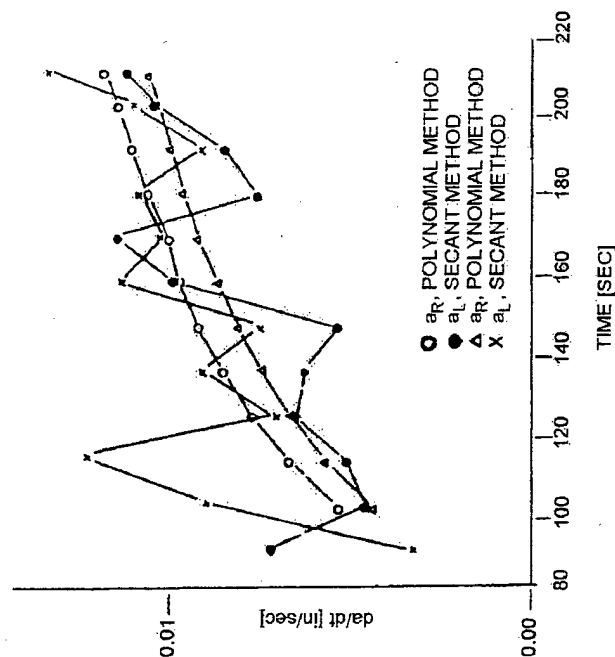
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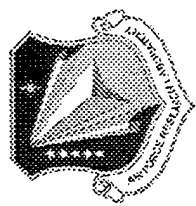
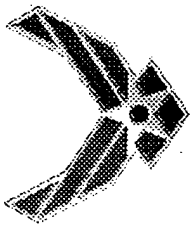
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Analysis of Data

Step 3: Relating Da/dt and K_I

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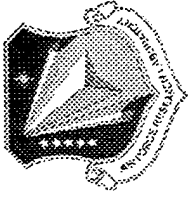
Summary and
Conclusions

- Da/dt and K_I can now be related for each test:

$$\frac{da}{dt} = CK_I^m$$



Results and Discussion



Introduction

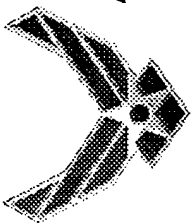
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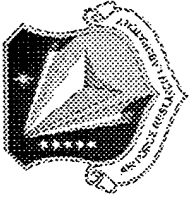
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Summary and
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- Ambient vs. Pressurized test condition comparisons
- SENT and surface cracked specimen comparisons



Ambient Vs. Pressurized Conditions



Introduction

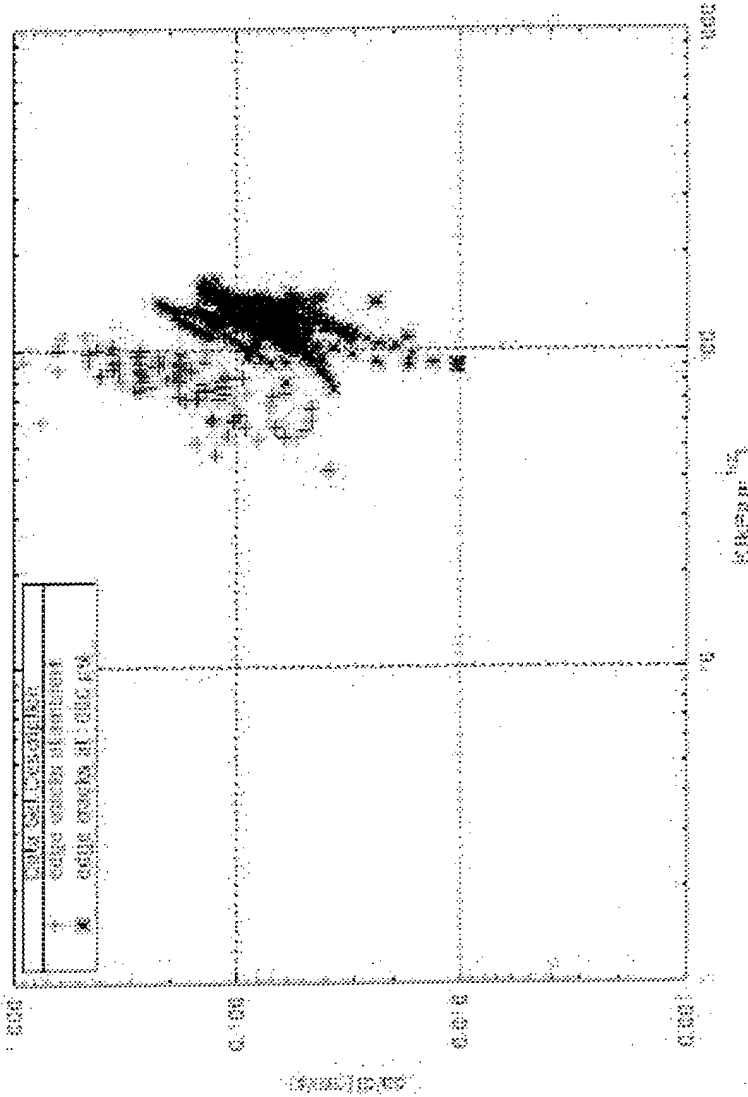
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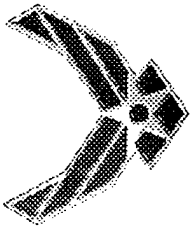
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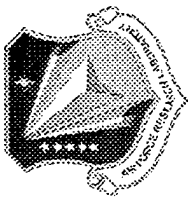
Summary and
Conclusions

- Pressure causes crack growth to slow
- Microstructural explanation
- Implication: ambient data may be overly conservative for pressurized service conditions





SENT and Surface Cracked Specimen Comparisons



Introduction

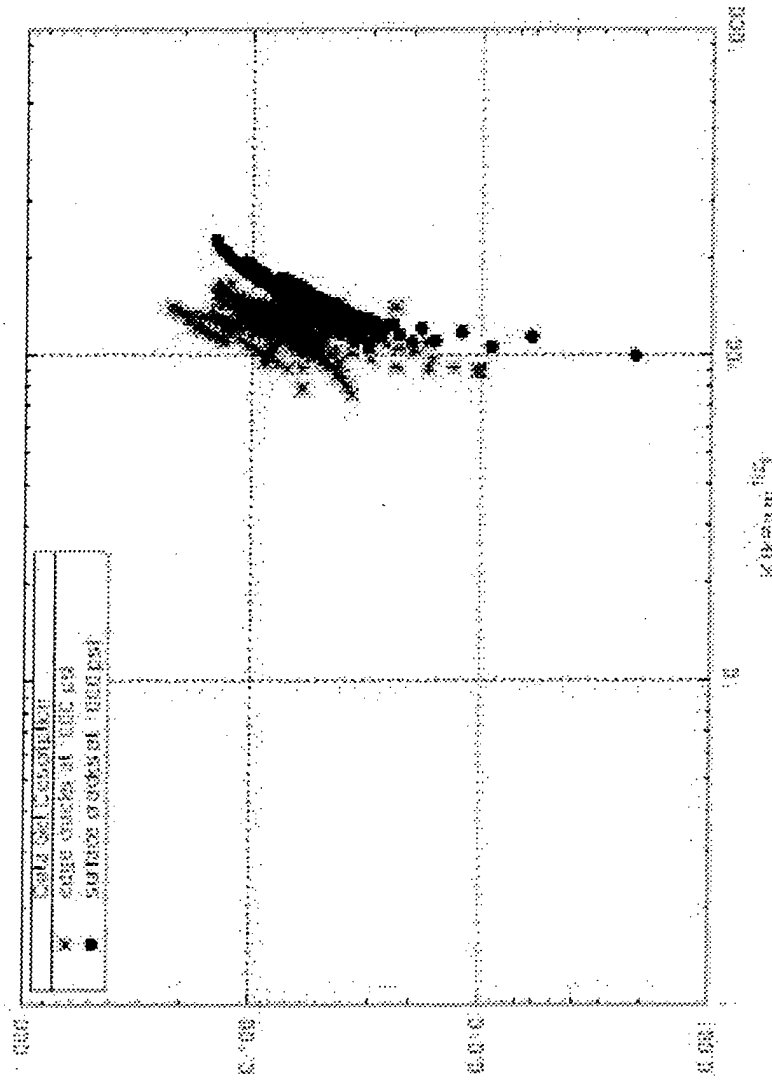
Experimental Procedure

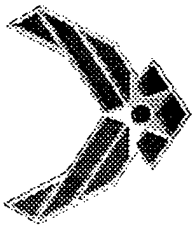
Analysis of Data

Results and Discussion

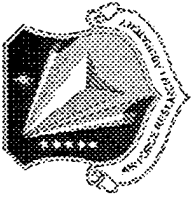
Summary and Conclusions

- Similar growth rates found for both geometries
- Implication: SENT data can be used instead of testing with surface cracked specimens





Combination of All Data



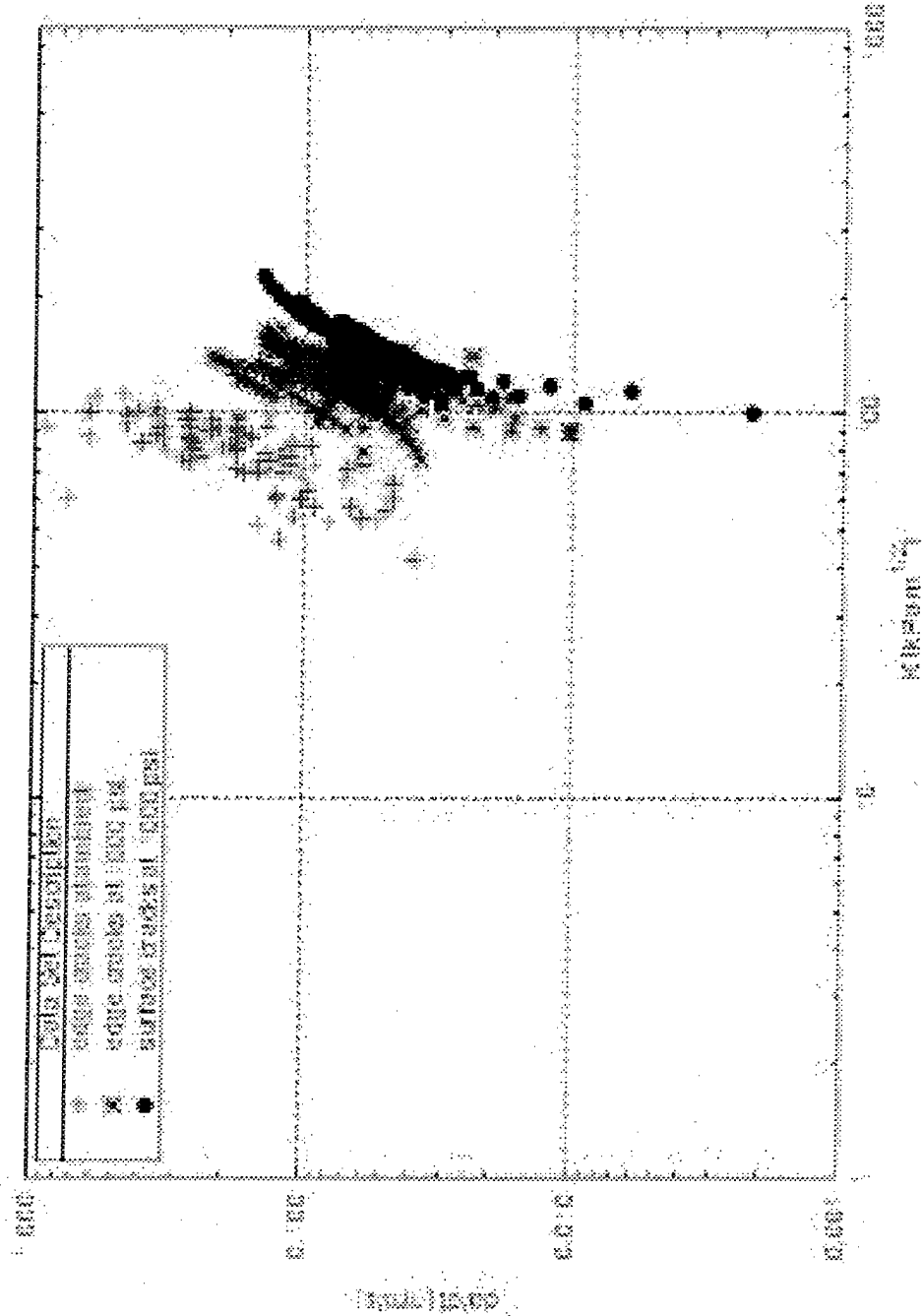
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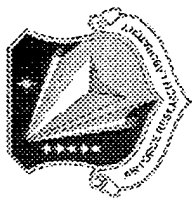
Analysis of
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Conclusions

What is the effect of pressure?

Summary and Conclusions



- **Summary:** this work has investigated the effect of pressure on fracture behavior of a rubbery particulate composite, and has compared the results for two different crack geometries under pressure. Pressure delays the onset of crack growth and slows the subsequent growth rate. The results for the two specimen geometries tested under pressure (SENT and surface cracked specimens) show good agreement.
- **Conclusions:**
 - Pressure inhibits the start of crack growth and slows the subsequent crack growth
 - Pressurized test data should be used to test for pressurized service conditions
 - SENT specimens can be used rather than surface cracked specimens

For the material and crack geometry considered in this study,